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ABSTRACT

Intended to aid in the design of computer systems that promote efficient learning and performance, this study compared the effects of using hard copy and online format tutorials on the learning activities of 48 undergraduate students in either design or engineering. The tutorials, which provided instruction on the use of the equipment and basic drawing functions of an IBM CADAM workstation for computer-aided design, contained identical content except for format modifications necessary to accommodate the different presentation modes. The study methodology is discussed, and a summary is provided of the study procedure, which involved two sessions during which students learned a total of four lessons, immediately after which they were tested, and a third session during which a retest was administered. Study results indicate that the online learners spent more time in learning than the hard-copy learners, primarily as a function of spending more time reading the tutorial. However, although the online tutorial resulted in more efficient performance on the immediate tests, performance on the retention test was less efficient, suggesting that, although the online presentation yielded greater short-term storage of information, less information was transferred to long-term memory. The text is supplemented with 13 tables, and 14 references are provided. (KM)

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Learning With On-Line and Hardcopy Tutorials

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January 1987

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Learning With On-line and Hard copy Tutorials

A

Final Report

by

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Communications Design Center, Carnegie Mellon University

for

International Business Machines Corporation
Kingston, New York

January 5, 1987

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Abstract

Learning under hard copy and on-line presentations of a tutorial was studied. The tutorial was for basic tasks using the IBM CADAM workstation for computer-aided design. The content for both tutorials was identical, however the format was modified to accommodate the different presentation modes. The on-line tutorial was a basic frame oriented presentation and did not branch based on student performance.

Students studied the first and last half of the tutorial on separate days. At the end of each session they received two tests, one on material they were directed to learn and one on incidental material. They were also brought back a week later for a retention test. All tests were performance tests using the CADAM workstation.

Results indicated that study time was distributed in the ratio of 13:7:1 over reading the tutorial, practicing on the CADAM workstation, and searching through the tutorial. The on-line learners spent more time in learning and that increase was primarily a function of more time spent reading the tutorial. The test results suggest that this increased time resulted in more complete studying of the material but that it was limited to immediate memory. Thus, the on-line tutorial resulted in more efficient performance on the immediate test but less efficient performance on the retention test.

Learning With On-line and Hard copy Tutorials

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"All they are doing is using the computer as a page turner -- why bother using the computer!" How often have we heard that lament about the design of computer-based instructional programs. The lament refers to a very common tendency to design computer-based tutorials as a sequence of frames, much like book pages, with expository text, examples, and some drill and practice. Perhaps there is some branching, but it is little more than looping back to earlier frames or perhaps adding a few extra frames of more basic information.

We may lament the failure to use the full capabilities of the computer, however there are many instances where just such "vanilla" instruction is necessary and perhaps even desirable. This is particularly true for tutorials on how to use a particular application software. The first task a new user faces when encountering a new piece of software is figuring out how to get started; how to use the basic commands. It is not just the computer novice that needs this assistance. The rapid growth and increased variety of application software and delivery systems has put even the very experienced computer user in the position of novice when he or she encounters new software. Furthermore, because of the variety of software packages, there frequently is no one available who has experience with the particular software. Thus, this previously common source of expert advice is lost. For these reasons, the tutorial has become an increasingly important factor in the successful use of application software.

While tutorials are an important component of the entire package, most tutorials do not involve elaborate presentation strategies. The time available for development is a primary consideration. Designing elaborate tutorials requires considerable time, typically more than the

software developer is willing to tolerate in terms of the consequent delays in getting the product to the market. Equally important, however, most users do not seem to want elaborate tutorials. The users, more than likely, have a particular application goal in mind. Using the tutorial is viewed as a necessary evil in achieving that goal. That is, the tutorial must be used to figure out how to use the program, but it is also taking up valuable time. Thus, even though the goal of the tutorial is to "teach", the time constraints are such that elaborate instruction, with branching to more basic explanations and requirements to master sub-objectives before progressing, is not desirable. Indeed, Carroll (1984) has proposed a minimalist design of tutorials to encourage the learners to explore the system to their own end.

Even if we believe that more complete instruction than the minimalist concept is necessary, it will still be very basic instructional design (Al-Awar, Chapanis, and Ford, 1981; Price, 1984). That is, an instructional analysis will lead to the specification of the concepts, facts, and procedures that must be presented to the learner. Then some basic expository content will be devised along with examples and some opportunities for practice -- the basic vanilla instruction. This instruction could just as easily be presented in hard copy or over the computer.

What criterion is the developer to use in making a media selection? From a financial point of view, computer-based delivery must be preferred. Both the cost of paper and the cost of mailing makes it far cheaper to distribute diskettes then it is to distribute manuals. Furthermore, it requires far less space to store diskettes then it does to store manuals. This is particularly true for the warehouse storage by the developer, but it may also be true for the learner as the number and complexity of learning requirements increases. Finally, updating or revising hard copy training materials has always proved difficult. On the one hand, the update may involve issuing a revised or second edition of the manual. The production costs of this approach can be enormous. Alternatively, change pages can be issued. Unfortunately, change pages seldom make it into the original manual. Updating a diskette, in contrast, can be a simple affair. The original diskette can be copied over or a diskette with the new version number can be issued.

While a financial analysis may weigh in favor of the computer presentation, what are the instructional consequences of choosing one or the other medium for delivery? There is rather consistent evidence that hard copy documentation leads to more efficient learning. Cohill and Williges (1985) and Dunsmore (1980) compared the two modes of presentation in the context of learning a database retrieval system. Cohill and Williges (1985) provided initial training using a manual and then compared hard copy help to four different on-line help strategies. The hard copy help led to faster performance and fewer errors than any of the on-line conditions.

Cohill and Williges provided all learners with initial instructions using a hard copy presentation before introducing the on-line/hard copy variable. Thus, they did fully separate hard copy and on-line instruction and may have created a transfer factor favoring the hard copy presentation. That is, the advantage of hard copy might have been due to the greater transfer within mode (hard copy initial learning to hard copy help) than between modes (hard copy initial learning to on-line help).

Cohill and Williges suggest two other reasons why their on-line presentation may have led to poorer performance. First, the on-line help replaced the task information on the screen. Thus, in contrast to the hard copy condition, the user had to remember the problem and the surrounding context while searching for help. As a consequence, the on-line learners faced much greater memory demands. Second, it was difficult to browse the on-line help. Learners would get lost in the help system.

While Dunsmore (1980) fully separated hard copy and on-line instruction, like Cohill and Williges, he required that the on-line documentation replace the task information. The potential consequences of such confounding are even more evident in this study. Dunsmore presented three groups of learners with brief or detailed on-line system documentation or the detailed information presented in hard copy. This information was presented for initial learning and during task performance. The clear finding was that detailed documentation presented on-line led to the poorest performance. There seemed to be little difference between the brief on-line and detailed hard copy instructions. Thus, it would seem that on-line presentation degrades

performance when that help information is elaborate. This was true even though the "elaborate" help was equivalent of only two pages of text.

The ineffectiveness of elaborate, on-line documentation can easily be interpreted as being due to the inability of the learner to hold the task information in memory while switching to the on-line documentation. With brief on-line documentation the memory and processing demands are not as great and thus performance is not degraded.

While Cohill and Williges (1985) and Dunsmore (1980) were examining database retrieval systems, we find much the same result in tutoring for other systems. Robertson and Akscyn (1982) compared the effectiveness of on-line and hard copy user manuals for learning a basic editor for the ZOG system. The information was meant to serve as a reference guide while the users performed a series of benchmark tasks. However, Robertson and Akscyn (1982) report that both hard copy and on-line learners tended to read through all of the source material before beginning any of the tasks. While there was no difference in the time for initial learning, they found the hard copy condition resulted in somewhat more efficient performance on a retention test.

Watley and Mulford (Schneiderman, 1987) found a hard copy tutorial for learning a drawing system was more effective than the on-line tutorial in terms of both initial learning time and subsequent retention performance. This was true for both computer experienced and novice learners. In contrast, Relles (1979) found the performance of experienced users to be better with on-line help while the novice performance was most effective with hard copy help. Not only were these performance effects found, but the effects were also reflected in the learners attitudes. Novice learners reported little confidence in their ability to use the bank management system with the on-line help while the experienced users felt comfortable with their ability to perform using those instructions.

In summary, the research consistently demonstrates that hard copy presentation leads to more accurate and faster performance. However, a significant factor in most, if not all, of the

studies was that the on-line information had to replace the task information. Rather than windowing, the single screen presented either help or task information and thus required the user to retain a detailed representation of the problem while he or she studied the help screen. In contrast, the hard copy permits the learner to keep both the task and the help information physically available for comparison. The difference in memory demands could be very significant and could account for much of the effectiveness of the hard copy in the Cohill and Williges (1985), Dunsmore (1980), and Robertson and Askcyn (1985) studies.

In the present research, learners received only on-line or only hard copy instruction and in both cases the information was presented separately from the task, thus controlling the requirement to remember the task during help searches.

The task involved the initial learning of a two-dimensional graphic design system called CADAM. The CADAM system involves a specialized workstation which prevents (at least for all practical purposes) the presentation of the tutorial on that system. Thus, the on-line tutorial was presented on a separate computer system. This approach to on-line tutorial instruction is representative of what we might expect to find in industrial training on the use of new equipment: the equipment is dedicated to the task and may not even have a display screen capable of presenting a tutorial. Thus, the training is presented on a separate system. It is also analogous to presenting the tutorial in a separate window on a system that has windowing capabilities.

The goal of the research was to aid in the design of computer systems that promote efficient learning and performance. Thus our goal is to understand just how on-line and hard copy presentations of the sort we have been discussing may affect learning activities. For example, Haas and Hayes (1986) found people had more difficulty locating information in an on-line text then they do with hard copy. They report that the readers appeared to lose a "sense of the text", i.e., a sense of the interrelationships and where information could be found. This is similar to the problem that Cohill and Williges (1985) saw their learners having with the on-line help and may even represent the confusion described by Relles (1979). We attempted to reduce

this problem by matching the on-line and hard copy tutorials by having the learners page rather than scroll through the on-line tutorial. Thus the "pages" could be designed just as book pages of a tutorial are designed, and the learner could develop a sense of position. We also provided an on-line index and glossary, parallel to ones in the hard copy tutorial, that a user could reach via a function key. When the user finished with the index, he or she could either return to the same place in the tutorial or go to a place identified in the index. A "bookmark" held the user's position in the tutorial. Therefore, if the user chose to go to a place identified in the index, he or she could still return to the original place in the tutorial.

While we attempted to provide as many book-like features as was feasible in a "basic" tutorial, we still anticipated that students might get lost as reported by Cohill and Williges (1985) and Haas and Hayes (1986). The on-line presentation simply does not provide the physical representation of the text; the learner does not have the physical cues to provide a reference point for browsing or even for interrelating different segments. The consequence of this should be that the on-line learners will spend a greater amount of time searching for information. Furthermore, this effect should be more pronounced in the test situation than in progressing through the tutorial. Thus, we would anticipate an increment in total time spent in learning and in the test due to the time spent searching for information.

A second unavoidable difference between the on-line and hard copy tutorials, which may affect learning and performance is the amount of information on a page. Rubens and Krull (1985) report that using 12 point Optima font, 7656 characters can fit on a standard 8.5 by 11 inch hard copy page. In contrast, the "normal" screen is limited to 24 lines by 80 columns or 1920 characters. Taking margins and typical spacing or leading into account, the number of characters for the 8.5 by 11 hard copy and the computer screen are 3792 and 1178 respectively (Rubens and Krull, 1985). In this research, there was a 2.5 to 1 ratio of on-line to hard copy pages for the primary instructional material.

We suspect there may be two consequences of this difference in the amount of information per page. First, it increases the amount of information one must sort through to locate the

relevant facts. Thus, it will further magnify the differences in the amount of time spent searching for information. Second, the learner will be more likely to read all of the information on the page. The on-line text has less information on a screen. Therefore, if a reader begins to read a page, i.e., given a fixed amount of progress through the "page", the on-line learners will have completed a greater proportion of their page and thus will have a greater tendency to complete reading it. In sum, the hypothesis is that there will be more thorough studying of the information in the on-line tutorial.

The third factor distinguishing on-line and hard copy presentations is the fact that it is psychologically and physically more difficult to skip pages in the on-line tutorial. While the hard copy user can physically grasp several pages at once and turn ahead, the on-line learner must pass through each page, pausing momentarily as required by the system response time. Furthermore, we suspect that being able to see the pages results in a greater tendency or willingness to scan ahead previewing and then return to the particular point in the lesson to continue with the detailed reading if that detailed reading was seen as necessary. With on-line presentation the learner cannot "see" the pages to skip ahead and may well feel uncomfortable in being able to return if such a venture were attempted.

We anticipate that these factors will further contribute to the on-line learner more thoroughly covering the instructional material. The on-line learners must pass through each page and thus pages will not be skipped as they often are in a manual. Furthermore, the learners (especially novices) most likely recognize that they probably will not glance back at the page later unless it is absolutely essential. There is greater cognitive effort in getting back to the on-line page than there is in getting back to the hard copy page. Thus, they will have a greater tendency to read the page.

The implications of these considerations are that the on-line learners may be expected to spend more time reading the tutorial text and will learn the information in the tutorial more thoroughly. The simple measure of time spent reading the text will not provide very strong evidence for the level of learning since there is already considerable evidence that it simply takes

longer to read a screen display than it does to read a comparable page of text (Brockman, 1986; Gould and Grischkowsky, 1983). For example, when given proofreading and comprehension tasks to be performed on a single screen/page of text, Moskel, Erno and Schneiderman (1984) found that the students working with hard copy had a 25% savings. Thus, we would anticipate our on-line learners to spend more time with the text simply as a function of perceptual factors.

However, if there is more thorough coverage of the content, not just more time consuming coverage, then we would anticipate more extensive learning of the tutorial. In particular, we would expect a higher level of incidental learning. We tested this hypothesis by providing the learners with a learning goal prior to studying each of the four lessons of the tutorial. These goals were meant to focus the learner's attention on roughly half of the tutorial. We then gave them two tests, one on the directed content and one on the incidental material. We anticipated that those students who learned on-line would have less need to return to the tutorial during the incidental test than would the hard copy learners.

Method

The CADAM System

CADAM, a computer-aided design and manufacturing system, is marketed by IBM. The CADAM workstation consists of a 3251 display, an alphanumeric keyboard, a function keyboard, and a puck and pad. A schematic of the system is presented in Figure 1. It is designed for use by engineers and designers in developing two-dimensional drawings. The workstation is linked to an IBM 3083 mainframe computer.

The display screen consists of four areas: a message area at the top, an area for typing commands at the bottom, a menu area just above that, and a drawing area which consists of the bulk of the display area. The alphanumeric keyboard is used for logging on and off, selecting files, entering notational data (e.g., part numbers, and design notes), entering coordinate and

angle information, and, through the use of the arrow keys, moving the cursor. There are twelve keys on the function keyboard laid out in a three-by-four matrix. The function keys are used to identify the kind of activity to be engaged in, e.g., making a line or placing points. Finally, the puck and pad are used to select elements on the display screen or to indicate where on the screen specific actions should occur. The pad provided a literal representation of the drawing area. Thus, the place of the puck on the pad indicated a specific screen location.

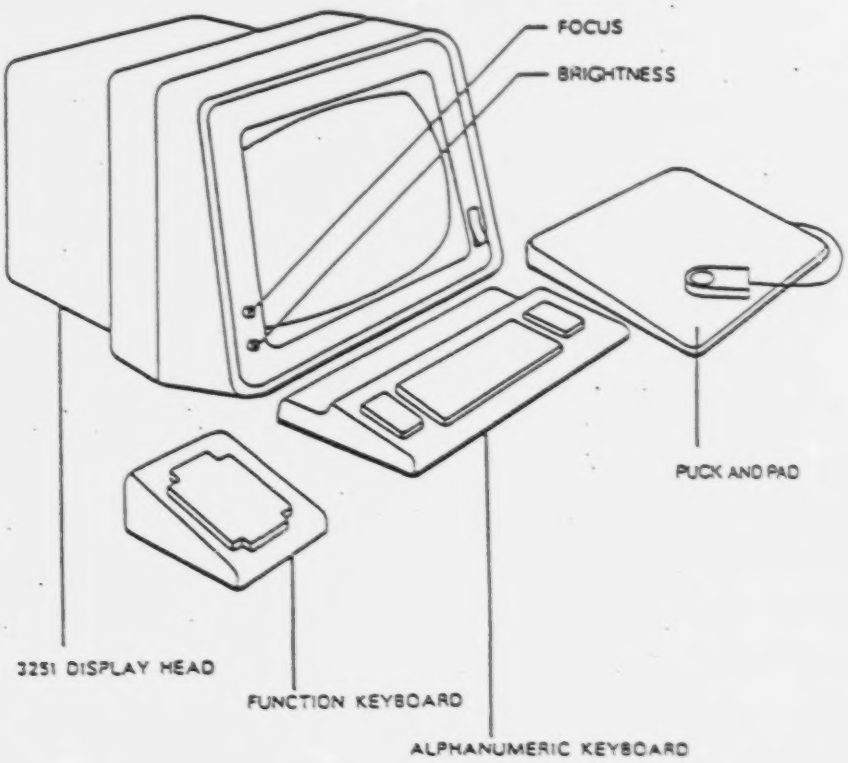

Figure 1. Schematic of the IBM CADAM workstation.

The Tutorials

Basic Content. The tutorials provided instruction on the use of the equipment and on the basic drawing functions. The bulk of the instructional material consisted of four lessons on the basics of constructing a drawing. The content of the lessons was as follows:

Lesson 1	logging on and off, starting and saving a drawing, and drawing points.
Lesson 2	strategies for constructing a line and how to make various types of lines.
Lesson 3	making sharp and rounded corners.
Lesson 4	moving a drawing around and through the window (display screen) and sizing the drawing.

Each of the lessons consisted of procedural instructions, giving the learner the action-response sequence required to achieve a particular goal. The learner followed the instructions by performing the sequence on CADAM. After each goal-oriented set of instructions, the learner was encouraged to practice the task on CADAM either literally, e.g., practice filing a drawing, or by trying variations, e.g., placing points in different places. A lesson concluded with a summary.

There were several sources of support for this primary instruction. A preface provided a description of the equipment and an overview of how and when the different components are used. The prefatory material also provided an overview of how to work through the tutorial. An index, consisting of 10 entries, provided a means of locating primary topics within the tutorial. In the hard copy version a page number was provided. In the on-line version the page number was provided and the learner could select the entry and the program would move to that section of the tutorial.

A glossary provided definitions of abbreviations used in the CADAM system. Finally, a help system provided suggestions as to what to do when something doesn't work, e.g., the cursor disappears or the function keyboard is frozen. The help system also provided interpretations for some of the error messages a learner might receive from CADAM.

On-line and hard copy. The basic, tutorial information was available for hard copy and on-line presentation. Both versions were initially developed by Ballay, Graham, Hayes, and Fallside (1985) for use with an earlier version of CADAM where a puck was not used and where the keyboard functioned somewhat differently.

Both of these earlier versions were reviewed for changes required to accommodate the new CADAM workstation, for inconsistencies between the hard copy and on-line versions, and for any errors in the information presented. Both the hard copy and on-line versions were rather extensively revised to achieve parallel instruction accurately reflecting the current CADAM workstation. The revised hard copy tutorial is presented in Appendix A while the diskettes for the revised on-line tutorial are in Appendix B.

In addition to identical content, the tutorials were both page oriented. That is, the learner paged through the on-line tutorial (rather than scrolling) and the pages were designed like hard copy pages, i.e., there were comparable formatting strategies. The number of the lesson was presented on each on-line page.

The two modes of presentation differed in three respects. First, the hard copy was presented on 8.5 in. by 11 in paper while the on-line tutorial was presented on a 24 line 80 column screen. The four lessons required 73 hard copy pages and 174 on-line pages. The same basic format strategy was followed with both presentations: use of headings, chunking information on a page, linking graphics and text, extensive use of white space, etc. However, because of the larger paper page, good design simply dictated that there would be more information on a paper than a computer "page".

The second difference between the hard copy and on-line tutorials was that highlighting strategies appropriate to the medium were used. Thus, while boldface might be used in the hard copy, flashing or reverse video would be used in the tutorial.

Finally, the on-line learners had to learn to use the computer for advancing through the tutorial and for searching for information outside of the sequence. The on-line tutorial was presented on an IBM PC-XT. Complete movement through the program was achieved through the use of the ten function keys. That is, the learner selected lessons, paged through the tutorial, moved to and from help and the index, etc., all by selecting the appropriate function key located

on the left side of the keyboard. The menu for possible function key selections was always presented in a row along the bottom of the screen.

If a learner went to the index, he or she scrolled through the index. At any point, an index item could be selected and the learner would be taken to the appropriate place in the tutorial. While in the index or in the subsequent section the learner could always select the function key to return to the original place in the tutorial. Similarly, the learner could move to and from the glossary and help through selection of the appropriate function key.

Test Materials

Lessons 1 and 2 were presented in one session and lessons 3 and 4 were presented in a session 24 hours later. Two tests were administered at the end of each session. In addition, a retention test on all of the lessons was administered one week after initial learning. All of the tests were performance based, i.e., the learner was required to perform some tasks on the CADAM system. In all of the tests, the learner had the tutorial material available for reference.

The tests administered at the end of each session involved a series of seven to nine activities that progressively built and modified a drawing. Both tests at the end of a given session drew on materials from both of the prior lessons. However, each test drew on different information in the lessons. That is, the two tests tapped non-overlapping information. Thus, for example, test A, after lessons 1 and 2, required the learner to log on, start a drawing, and make a series of points using a particular technique. Test B presented the learner with a blank drawing screen and required the learner to place some points using a different technique and then save the drawing and log off.

The learners were told prior to beginning each lesson of the tutorial that particular information would be on the test. One of the two tests at the end of the session tested that information while the other test was on topics not mentioned. Thus the two test tapped "directed" and "incidental" learning. Of course the particular information identified as "relevant" at the

beginning of the tutorial was counterbalanced across learners so that a test that was on directed material for half the subjects was on incidental material for the other half.

A single retention test was administered between 6 and 8 days after the second learning session. The test involved 10 steps that drew from all four lessons and from the topics of test A and test B.

All tests are presented in Appendix C.

Performance Measures

Time spent on various activities was measured during the learning, test, and retest sessions. The key activities were total time, time spent reading the tutorial, time spent searching in the tutorial, and time spent working at CADAM. Working on CADAM was defined as the learner's head being primarily oriented toward the CADAM work station and his or her hands being on the CADAM keyboards. Thus, if the learner was carrying out tutorial instructions on the CADAM system, his or her hands would be on the CADAM station and the head would either be focused on CADAM or glancing back and forth between CADAM and the tutorial. This time would be logged as CADAM time. Similarly, straight practice on CADAM or carrying out test activities on CADAM would also be considered CADAM time.

Tutorial Study Time was only logged during the learning sessions. This was considered any time the learner's hands and head were oriented toward the tutorial and the instructional page was appropriate to the progress through the tutorial, i.e., the learning was working through the tutorial in a linear fashion.

Tutorial Search Time was considered any time the learner was moving around between pages of the tutorial or rereading previous material. If the learner simply went back a page to reread, this was still considered learning activity. The search activity involved a distinct movement from the primary flow of the tutorial. All use of the tutorial during the test and retest sessions was considered Search Time.

Total time in learning was the time from the beginning of the lesson to the time the person indicated the lesson was complete. In testing and retesting, Total Time was measured from the point at which the learner was handed the problem to be completed until the time at which the problem was solved. In retest, the problem was not given to the learner until he or she had reviewed the instructions for using the tutorial. This latter time was not logged in the experiment.

Finally, accuracy of performance was scored in each test session. Each problem had between 5 and 8 distinctive components and each component was scored as correct or incorrect. While there were several steps in each problem, there was a dependency between the steps such that completion of a given step provided the "set-up" necessary to complete the next step. Because of this linkage between steps, as well as the fact that the problems all had very concrete solutions and the students always had the tutorial available, it was anticipated that mastery performance would be obtained. In essence, it was a basic tutorial and all the information was available to complete very concrete problems. The main difference between groups was expected to be in the time measures.

Design

There were a total of sixteen experimental conditions. These conditions reflected the independent manipulation of the two primary between-subjects factors (Tutorial in initial learning and Tutorial in retesting) as well as the requirements for counterbalancing the presentation of the within-subjects variables. Different independent and dependent variables were involved in the learning, test, and retest sessions and thus we will present the design considerations for each separately.

Learning. The design for evaluating learning activities consisted of a 2-by-4 mixed factorial. The between-subjects factor was Mode of presentation (on-line or hard copy) while Lesson Number (1 to 4) was a within-subjects factor. The dependent measures all related to time spent in learning: study, search, CADAM, and total time.

Test. A 2-by-2-by-2 mixed factorial design was used to evaluate test performance. The between-subjects factor was Mode of presentation (on-line vs hard copy). The within-subjects factors were Test Sessions (after lesson 2 or 4) and Incidental Learning (the test information was either noted prior to instruction or not). Which form was designated as directed (form A or B) and whether the directed test was presented first or second was counterbalanced across subjects.

The dependent measures were accuracy (proportion of steps correct), total time, CADAM time, and tutorial time.

Retest. There were two between-subjects variables in retest: Initial Learning Tutorial and Retest Tutorial. In retesting, the mode of the tutorial available was either the same as was used in initial learning or it was switched to the opposite mode. Thus, half of the those who learned and were initially tested using the hard copy tutorial were retested where only the on-line tutorial was available. Similarly, half of those who learned and were tested with the on-line tutorial available, now had only the hard copy tutorial available. The other half of the learners continued to have the same mode of tutorial available as was available in initial learning.

Learners

A total of forty-eight learners were tested. They were second, third or fourth year undergraduate students in either design or engineering. While some of the learners had heard of CADAM, none had any prior experience. Participation was voluntary, but participants were paid $20 for completing all three sessions.

Procedure

The experiment was conducted in three sessions. In the first session, learners worked through the initial material, lessons 1 and 2, and the two tests on those lessons. In the second session, which occurred the next day, learners completed lessons 3 and 4 and the tests on those lessons. The final session, retest, occurred between 6 and 8 days after the completion of the second session.

The learner was seated at the CADAM workstation with the IBM PC-XT to the left of the workstation. The learner was then given a written set of instructions. The experimenter reviewed the instructions with the learner. The instructions told the learners that they would be learning how to use CADAM to draw, that they would complete two lessons on the first day and two on the second day. They were also told that, at the conclusion of a session, they would receive an open book test on the day's learning. Finally, they were told they would return a week later for a final, open book test.

The learners were told to begin the tutorial by reading the material on CADAM and on the use of the tutorial. They were told that the test at the end of the session would focus on specific topics covered in lessons 1 and 2. The list of topics was specified verbally and the written list was placed next to the CADAM workstation for reference during instruction. At the beginning of the session on day two, the learners were given a similar list of topics from lessons 3 and 4 to be tested at the end of the session.

After completing the two exercises for a session, the learners were given one of the two tests. They were told to complete the tasks as described and that they could use the tutorial as needed. After completing the first test, the learners were given a second test and told to complete those tasks, again using the tutorial as necessary.

The same procedures applied in retest. The learners were ask to complete a series of tasks listed on a test sheet. They were shown the tutorial and told they could use it as necessary to complete the tasks.

The experimenter sat about 5 ft. behind the learner during all of the sessions. Time data was recorded using a time program on the IBM PC. The program recognized 5 possible keystrokes the experimenter could make. The key strokes signaled the beginning or end of a session and the end of studying, searching, or CADAM practice activities. The experimenter pressed the appropriate keys based on observation of the learner's head and hand movements as

described earlier. The keystrokes thus served as time stamps on a running clock. The output was total time in each of the three activities during each learning session and during each test.

During learning, the clock was begun when the student turned to the first page of the tutorial for a given lesson and was stopped when the student indicated he or she had completed that lesson. Each lesson was timed separately. In testing, the time for the session began when the student was handed the problem description and ended when the problem was completed. Each test was timed separately. In retest, the learner was given the opportunity to review the prefatory material (for half of the students the mode of the tutorial had changed) on the tutorial and on CADAM before the problem was presented and the timing began. The retest session was timed like the test session.

There was one final timing activity. It was possible for the learner to crash CADAM or for the system to go down momentarily for other reasons. The experimenter kept a stop watch to time any such "extra-experimental" event. The time from the occurrence to the correction of the event was subtracted from the appropriate time measures for the session.

The experimenter did not answer any questions during learning and did not interrupt learning or test activity unless the learner was stuck and could not progress. For example, if the learner accidentally logged off and could not figure out how to log back on or if the learner simply couldn't execute a tutorial or test directive, the experimenter would give the learner the step or steps, without explanation, necessary to progress. A five minute period of no progress was required before such advice was given.

Results and Discussion

Learning Time

Looking first at learning time, we find that students using the hard copy tutorial took less time on every lesson than those students using the on-line tutorial. As shown in Table 1, the total

time to complete the entire tutorial was 107.5 and 92.0 minutes for the on-line and hard copy conditions, respectively. This is a 14% saving in learning time for users of the hard copy tutorial. A 2-by-4 ANOVA yielded significant main effects of Mode of Presentation, $F(1,46)= 4.83$, $p<.05$ and Lessons, $F(3, 138)= 238.5$, $p<.001$. The latter effect simply reflects the fact that the first two lessons were much longer than the second two.

Table 1

Mean (& standard deviation) of the total time (in seconds) spent learning

	Lesson 1	2	3	4	total
Online	2349 (536)	2303 (588)	930 (419)	868 (196)	6450
Hardcopy	2002 (604)	2020 (654)	851 (327)	648 (227)	5521

It would seem that most of the increase in learning time with the on-line tutorial can be accounted for by an increase in study time. As shown in Table 2, on-line learners spent more time reading in each of the four lessons. Overall the time spent reading was 66.0 minutes on-line and 56.1 minutes using the hard copy tutorial, for a 15% time savings when using the manual. A 2-by-4 ANOVA indicated that both main effects and the interaction were significant. The main effect of Mode of Presentation yielded an $F(1,46)=4.66$, $p<.05$ while the Sessions main effect produced an $F(3,138)=412.6$, $p<.001$. The interaction of Sessions with Lessons yielded $F(3,138)=4.79$, $p<.05$.

Table 2

Mean (& standard deviation) of the time (in seconds) spent reading during the tutorial

	Lesson 1	2	3	4	total
Online	1840 (397)	1178 (269)	422 (215)	518 (139)	3958
Hardcopy	1503 (458)	1128 (402)	355 (151)	382 (134)	3368 (397)

The interaction would seem to be due to a relatively greater savings in time during the last two lessons (the second session). Using the hard copy tutorial resulted in a 21.2% time savings during the second session but only a 13% savings in the first session. The interpretation of this effect is unclear. It could mean that the hard copy users learn how to use the manual and this learning transfers to the next session. In essence it would suggest that the advantage of hard copy documentation grows with experience. Alternatively, however, session two was much shorter than session one and thus the greater relative gain may simply be an artifact of the smaller base.

The on-line students also spent more time searching and rereading information. In the 2-by-4 ANOVA of search time, only the main effect of Mode of Presentation was significant, $F(1,45)= 5.1$, $p<.02$. As shown in Table 3, the significant effect reflects the prediction that on-line learners would have greater difficulty locating information. However, since the student was progressing through a linear tutorial, locating information was seldom required. Thus, although a significant factor distinguishing learning performance under the different tutorials, search time was not a major contributor to the total time it took a student to complete the tutorial. Of the total

learning time, hard copy students spent 61.0% reading and only 4.0% searching. These values were 61.3% and 5.3% respectively, for the on-line learners. Given that search time was a significant between groups factor under these conditions, we would anticipate it would be a major contributor to the time spent on the test items, when searching for information is more likely to be a requirement.

Table 3

Mean (& standard deviation) of the time spent searching for information during the tutorial

	Lesson				
	1	2	3	4	total
Online	61 (100)	147 (119)	95 (109)	45 (93)	348
Hardcopy	49 (55)	71 (65)	81 (98)	20 (71)	221

The mean time spent practicing on the CADAM workstation during each lesson is presented in Table 4. The hard copy learners spent an average of 32.2 minutes working with CADAM while the on-line learners spent an average of 35.7 minutes. Neither this main effect of Mode of Presentation nor the interaction of Mode with Lessons yielded significant differences, $F(1,46)=.83$ and $F(3,138)=1.5$, respectively, $p>.10$. However, the main effect of Lessons was significant, $F(3,138)=71.4$, $p<.001$.

Table 4

Mean (& standard deviation) of the time spent practicing CADAM during the tutorial

	Lesson 1	2	3	4	total
Online	434 (146)	981 (461)	416 (168)	308 (122)	2139
Hardcopy	449 (161)	821 (440)	414 (275)	245 (204)	1929

In summary, we find that students learning CADAM distributed their learning time across reading, practice and searching-rereading at a ratio of about 13:7:1. The hard copy tutorial required significantly less time to complete (14% less time) and that time can be accounted for primarily by decreased reading time. However, searching and rereading time also contributes to the difference in total learning time.

Test Performance

Tests were administered at the end of each session (after every two lessons). Test-Type was a factor in this testing: one test was on cued material (direct) and one on uncued material (incidental). Within a session, Test-Type was counterbalanced with order of presentation and with the particular test problems.

All test data was lost on one on-line learner due to a recording error in the computer data collection program. The search and CADAM time data were lost on another three on-line

learners and three hard copy learners due to recording errors. Thus full test data is on only 41 of the 48 learners.

The mean proportion correct on the tests as a function of Mode of Presentation, Test-Type, and Sessions is presented in Table 5. The tutorial was available to the student during the test and the test called for producing particular screens. Furthermore the questions called for very concrete solutions and thus the student could always tell if a correct answer was achieved. Because of these factors, we anticipated near perfect performance by the learners. The generally high scores for the proportion correct presented in Table 5 reflect this anticipated ceiling effect. Since mastery performance was anticipated and since there is an obvious skewness in the distribution due to the ceiling effect, these data were not subject to analysis.

Table 5

Mean proportion correct on the direct and incidental tests

Test Topic	Tutorial	Session 1	Session 2	$\bar{X}$
Direct	Hardcopy	.942	. 942	.942
	Online	.857	.949	.903
Incidental	Hardcopy	.929	.958	.943
	Online	.920	.960	.940

The effect of the instructional variables should, however, be reflected in the time data. That is, we would expect the incidental test to require more time since the learners would not have given as much attention to the relevant information in the tutorial during learning. Further, we would expect the on-line learners to require less total time on the test, and less total time on

the incidental test in particular, because of the hypothesized more thorough reading they would have given to the tutorial information.

The time data for test performance was highly skewed to the right reflecting the typical baseline effect of timed tests. Thus all analyses were performed on the log transformation of the time scores.

The total time to complete a test is presented in Table 6 where it can be seen that the effects are in the predicted direction. First, the on-line group took less time than the hard copy group to complete the tests. Across both tests there was a 7.4% savings for the on-line group. Thus we see a reversal from the learning phase where we found the on-line group took more time.

Table 6

Mean (& standard deviation) of the total time (in seconds) spent on each type of test

		Session		
Test Topic	Tutorial	1	2	$\bar{X}$
Direct	Hardcopy	.942	.942	.942
	Online	.857	.949	.903
Incidental	Hardcopy	.929	.958	.943
	Online	.920	.960	.940

Again as predicted, the effect was more substantial for the incidental test. The on-line group completed that test 12.3% faster than the hard copy group while the savings was only 1.9% on the direct test. While the switch from direct to indirect seems to have little effect on the

time for the on-line group, the hard copy learners showed a substantial (9.7%) increase in time to complete the incidental test. It would seem that the extra time the on-line group spent in learning (see Table 1) may have led to more incidental learning and thus facilitated test performance.

While the data in Table 6 suggest that our hypotheses were confirmed, the data analysis failed to support the reliability of the differences. A 2-by-2-by-2 repeated measures ANOVA of the data in Table 6 only yielded a significant effect due to Sessions, $F(1,45)=8.4$, $p<.001$. Performance was better (faster) in the second session. Neither the main effects of Mode of Presentation and Test-type nor the interactions were statistically significant.

The time spent working with the tutorial during the test phase is presented in Table 7. These data include both searching for information and rereading parts of the tutorial. The data indicate that the on-line group spent 24.5% less time than the hard copy group using the tutorial. Again this is as predicted. We also predicted that there would be an interaction such that the hard copy group's greatest need for the tutorial would be in completing the incidental test. The data in Table 7 suggest there may be an interaction as predicted. The on-line group had a 28.3% savings on the incidental test but only a 20% savings on the direct test.

Table 7

Mean (& standard deviation) of time (in seconds) during each test spent searching or rereading the tutorial

Test Topic	Tutorial	Session 1	Session 2	$\overline{X}$
Direct	Hardcopy	242 (66)	252 (109)	247
	Online	251 (132)	246 (134)	249
Incidental	Hardcopy	296 (129)	279 (119)	287
	Online	283 (116)	252 (139)	267

Once again, the data analysis failed to confirm the reliability of the differences. The 2-by-2-by-2 repeated measures ANOVA only yielded a significant effect due to Sessions, $F(1,26)=9.1$, $p<.001$. While the difference between means for both total time and for reading time are large enough to suggest a practically significant difference, the analysis did not indicate statistical significant differences. An examination of the data presented in Tables 6 and 7 indicates that the lack of statistical significance -- the lack of reliability -- is a function of the unusually large variance in the scores. The standard deviation of the read/search times ranged between 116 and 219, roughly the same range as we find for the mean scores.

We attempted to reduce variability by creating a new variable, speed of learning, that would reduce individual differences. Learners in each Mode of Presentation group were divided into fast and slow learners based on the time spend in the learning phase of the experiment. That is, participants in each Mode of Presentation condition were placed into high or low learning speed groups based on whether they were above or below the median learning time for that group. 2-by-2-by-2-by-2 ANOVAs with Mode of Presentation and Ability as between-subjects factors and Test-Type and Sessions as within-subjects factors were carried out on the Total time and Tutorial time. The results confirmed the earlier analyses -- neither the effect of Mode of Presentation nor the effect of Test-Type approached significance.

We next attempted to reduce variability by using the total test time as a base for examining the time with the tutorial. That is, we created a new dependent measure: the proportion of the total test time spent reading and searching through the tutorial. Variance due to individual differences in ability should be reduced since the base for each person is his or her learning time. It is also a very meaningful measure since we are predicting that the reason on-line learners will spend more time on the test is that they are spending more time with the tutorial, i.e., the proportion of the total time involved in reading or searching the tutorial should be greater for the hard copy learners. Similarly, the hypothesis for the effect of the incidental vs direct test is that the former should require the learner to spend a greater proportion of the total time searching for information.

The proportion data is presented in Table 8. A 2-by-2-by-2 ANOVA of these data indicated that only the main effect due to Sessions was significant, $F(1,39)=10.1$, $p<.01$. While not significant, the direction of the relationships in Table 8 are consistent with the previous analyses: the on-line learners spent a smaller proportion of the total test time looking back over the tutorial. However, there is no suggestion of an interaction with Test-Type.

Table 8

Mean proportion of test time spent with the tutorial

Test Topic	Tutorial	Session 1	Session 2	$\bar{X}$
Direct	Hardcopy	.36	.31	.33
	Online	.31	.23	.27
Incidental	Hardcopy	.34	.30	.32
	Online	.28	.26	.26

The final dependent measure was time spent working on the CADAM system. The results, presented in Table 9, suggest that on-line learners spend somewhat less time 7.0%) on CADAM while completing the incidental test. A 2-by-2-by-2 ANOVA of these data failed to yield any significant main effects or interactions.

Table 9

Mean (& standard deviation) of time (in seconds) spent on CADAM during each test

Test Topic	Tutorial	Session 1	Session 2	$\bar{X}$
Direct	Hardcopy	242 (66)	252 (109)	247
	Online	251 (132)	246 (134)	249
Incidental	Hardcopy	296 (129)	279 (119)	287
	Online	283 (116)	252 (139)	267

Retest data

Retesting took place seven days after the second session. The learners were given a task that required the application of information used in all of the four tutorial lessons. The two primary variables in this test were the Mode of Presentation for the initial learning and Mode Consistency between learning and retest. Half of the on-line learners were given the on-line version in retest while the other half were given the hard copy. The same split occurred for the hard copy learners. Seven on-line learners and six hard copy learners failed to return for the retest, thus reducing the total N for retest to 35.

The mean proportion correct in retest is presented in Table 10. Mastery performance was anticipated since the tutorial was available during the test and the concreteness of the task provided clear feedback to the learner as to whether or not the solution was correct. As the data

in the Table indicate, the anticipation was met. Mean performance varied between .94 and .97. These data were not analyzed any further.

Table 10

Mean proportion correct on the retest

Learning Tutorial	Retest Tutorial: Same	Retest Tutorial: Different
Hardcopy	.96	.97
Online	.94	.96

A retest session began with the learner being told that he or she was going to have a final problem to complete using the CADAM system and that the on-line (hard copy) tutorial would be available for reference. The learner then read through the "how to use this tutorial" section. Finally, the problem was presented. Timing of the session did not begin until the learner received the problem.

The total time to complete the retest is presented in Table 11. The data indicate that using the hard copy tutorial throughout resulted in the shortest total time while using the on-line tutorial throughout resulted in the longest total time. Indeed, consistent use of the on-line tutorial resulted in a 26.5% savings in time relative to consistent use of the hard copy tutorial. Using the on-line tutorial after having learned with it is even worse than switching to the on-line tutorial for the first time.

Table 11

Mean (& standard deviation) of the total time (in seconds) to complete retest

Learning Tutorial	Retest Tutorial: Same	Retest Tutorial: Different
Hardcopy	760 (303)	896 (457)
Online	1035 (336)	861 (501)

Similar results are indicated in the time spent using the tutorial during the retest. As shown in Table 12, The participants who learned with the on-line tutorial and were tested with it spent the greatest amount of time using the tutorial. Participants consistently using the hard copy tutorial spend 30% less time and even those people using the on-line tutorial after having learned with the hard copy spent 22% less time.

Thus the data suggest a reversal from initial testing. While the on-line tutorial facilitated performance on an initial test and resulted in less time spent looking through the tutorial, we now find using the on-line tutorial requires far more time. In essence, it would seem that the extra learning time spent with the on-line tutorial resulted in only very short term benefits.

Table 12

Mean (& standard deviation) of the total time (in seconds) during retest spent searching and rereading the tutorial

Learning Tutorial	Retest Tutorial: Same	Retest Tutorial: Different
Hardcopy	293 (292)	326 (418)
Online	420 (219)	247 (301)

Unfortunately, as with the immediate test data, the statistical analysis of the data failed to confirm the reliability of the differences. Separate 2-by-2 ANOVAs on the total time and tutorial time data failed to yield significant main effects of Initial Mode of Presentation or the Consistency of Presentation or a significant interaction. As in the immediate test data, the variability is very high, roughly equivalent to the size of the means of the tutorial times.

The time spent during retest actually working on the CADAM system is presented in Table 13. Again the results suggest indicate that the consistent use of the hard copy tutorial resulted in the shortest time. However, a 2-by-2 ANOVA of the data again failed to yield any significant effects.

Table 13

Mean (& standard deviation) of the total time (in seconds) during retest spent working on CADAM

Learning Tutorial	Retest Tutorial: Same	Retest Tutorial: Different
Hardcopy	499 (121)	570 (109)
Online	615 (174)	614 (226)

Conclusions

Previous research has rather consistently found on-line information to be less effective than hard copy. The effect has been attributed to many different characteristics of the on-line help. In some cases, the on-line learners were required to replace the application screen with the help or tutorial screen thus creating a differential memory demand that could account for the effects. In other cases it was suggested that on-line learners simply got lost in the on-line information. A third line of argument has been that the perceptual demands of the screen simply require longer reading times.

While we basically confirmed the increased time required to use an on-line tutorial, the interpretation of the results is quite different. Separating the tutorials from the application software removed the common confounding of screen memory requirements. Furthermore, an assessment of learning activities clearly confirms that getting lost is not an important factor, at least during initial learning. This does not suggest that it was necessarily easy to get around in the on-line tutorial. Rather, since this was a learning phase the student was progressing linearly through the tutorial and there was little need to search around for information.

The results do suggest that the extra time spent by on-line learners was primarily attributable to extra time spent reading the tutorial. That is, most of the differences in total time could be attributed to time spent reading the tutorial rather than time spent searching through the tutorial or working with the application. This extra time spent reading could mean the learners were giving more attention to the information, i.e., learning more, or it could simply mean that there were greater perceptual demands in reading the screen. The latter explanation is bolstered by a variety of studies, e.g., Moskel, et.al. (1984), that found individuals take longer to search through an on-line presentation than they do hard copy.

It is the results in testing that suggest that the effect is not purely perceptual but rather reflects the fact that the on-line learners are reading the text more thoroughly. That is, we find that while the on-line learners spent more time during learning they required less time to complete the tests. The difference between on-line and hard copy groups was greater on the incidental tests than on the direct test. Thus the on-line learners would seem to have spent more learning time on the non-directed (the incidental) material. This is consistent with our hypothesis that the on-line presentation will result in more thorough reading of the tutorial.

Importantly, the advantage for on-line learners is short lived. In retest a week later we find yet another reversal in the relative amount of time required by on-line and hard copy learners. It is now the individuals who initially learned on-line who require the greater amount of time. And the extra test time is primarily due to extra time spent reading the tutorial.

This reversal suggests that the extra learning time spent by on-line learners did not result in deeper processing of the content, i.e., better learning. Indeed the on-line learners even required more time than those participants who also using the on-line version in the test but had initially learned by hard copy. This would suggest that the on-line presentation, while yielding greater short term storage of information, resulted in less information transferred to long term memory. The reason for this difference is not clear. We had hypothesized that the on-learners would tend to page around less than the hard copy learners during initial learning, simply because they would be afraid of getting lost in the tutorial. We did not test this hypothesis in the present study but if it is true then we would expect that the hard copy learners, by moving around more freely in the tutorial, would reread and integrate the information (that was attended to) more thoroughly. This integration, in turn, would result in a more stable storage of the information in memory.

The above analysis is based on a consideration of the differences in the descriptive data that appear large enough to be of practical significance. The parametric analysis, unfortunately, did not confirm the reliability of these difference. Based on the tests for statistical significance, we can only conclude that learning with the on-line tutorial requires more time then learning with

the hard copy tutorial and that the primary factor in the difference is the time spent reading the tutorial.

The large variance in the test data seem to responsible for the lack of statistical significance. Since we did obtain statistically significant differences in learning it does not seem that the lack of an effect in the testing can be due to the lack of rigorous methodological procedures. Analyses of the test data that took ability into account did not result in significant treatment effects. Furthermore, the large variance does not appear in the learning data. Thus the factor or factors accounting for the variance would seem to rest in the test taking strategies and not in a general ability variable. Unfortunately, only additional testing will aid in untangling this problem.

In summary, the statistical analyses indicate that on-line tutorials require more time to complete and that the time difference seems to be primarily accounted for by reading time. The large effects in the descriptive data for testing suggest that on-line learners read the tutorial more completely (it is not just a perceptual problem) and that thoroughness of coverage aids immediate performance. However, it is a breadth rather than depth effect and thus the effect is not sustained during a retention phase. Furthermore, when the tutorial must be used as a reference, as in the retest phase, it is far less useful.

In addition to the conceptual understanding of the effects of the tutorial, there are some summary statistics that should be used for comparison purposes in future analyses of on-line and hard copy information. In general learners seem to distribute their learning time across reading, practice, and searching in the ratio 13:7:1. The on-line tutorial required 16.8% more time to complete in learning. However, the immediate tests were completed 7.4% more quickly. The savings were more substantial on incidental test material (12.3%) than on direct material (1.9%). In contrast, in the retention test one week later, consistent use of the hard copy tutorial resulted in a 26.5% savings relative to consistent use of the on-line tutorial. These data clearly reflect the short term benefits but long term consequences of the on-line tutorial.

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